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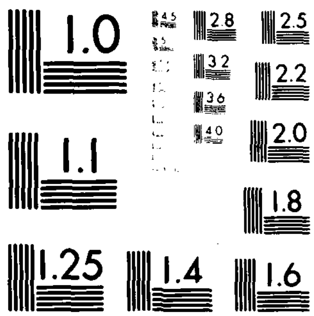

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Technical Note 14-80

A PRELIMINARY HUMAN FACTORS FLIGHT ASSESSMENT OF A MARCONI AUTOMATIC MAP READER

Thomas L. Frezell

October 1980

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U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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A Marconi Automatic Map Reader was flight tested in low level, enroute, and nap-of-the-earth flight profiles to determine its suitability for navigation. The results obtained from these flights demonstrated a viable potential of the Marconi AMR as an interim navigation system.

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CONTENTS

A PRELIMINARY HUMAN FACTORS FLIGHT ASSESSMENT OF A MARCONI AUTOMATIC MAP READER

INTRODUCTION

The ability to accurately navigate during nap-of-the-earth (NOE) flight is imperative for successful helicopter combat operations. Aircraft navigation has been identified as the primary problem area in achieving an effective NOE capability (1). It has also been recognized that navigation by visual cues and dead-reckoning are no longer considered viable solutions to the problem.

For example, experiments carried out in the early 1970's by the US Army Combat Development Experimental Command (USACDEC) (8) demonstrated navigational difficulties flying NOE routes with Cobra helicopters. Several major course deviations (500-2000 meters) occurred and the chase aircraft had to redirect several crews to enable them to complete the course. These assists were not considered in the performance measurement. In a later USACDEC Experiment 43.7 (7), the conclusion reached with regard to night NOE flight was:

> "Specifically, there is no standard or immediately available integrated system for helicopters to navigate singly, or as a team, at an altitude that ensures survivability against known threat air defense systems, and to acquire and engage tank targets, at any range, in unfamiliar terrain at low levels."

An Army Research Institute (ARI) study conducted in 1974 on the ability to upgrade pilots' navigational capabilities is best summarized by McGrath (5). The probability of navigating at NOE to within 100 meters of an identified Landing Zone (LZ) was .77. It would be difficult to explain to a field commander that he could not depend on one fourth of his aviation assets simply because they could not find their way to the destination. The majority of evidence would tend to indicate that unaided navigation at NOE altitudes will result in substantial attrition rates even during daylight operations. The results obtained in the USACDEC experiments show aviators became disoriented enroute during 33% to 50% of the test sorties. Attempts to reorient them produced such extreme variability, in the time required to navigate a given route, that any capability for conducting coordinated attacks would have been seriously compromised.

There is an abundance of literature available that addresses the navigation problem and man's ability to orient himself during flight operations. One's ability to orient himself is probably best expressed by Lichte *et al* (4) in the following excerpts:

(1) "There is no innate sense of direction nor ability to maintain orientation."

(2) "When unrecognized errors are made, those factors that normally lead to a confident, complete and persistently correct orientation, tend to produce equally confident but completely incorrect orientation, with the same degree of persistence."

(3) "Individuals differ in their orientation ability, both in terms of the extent or scope of their orientation and in their ability to maintain orientation and recover orientation once they have been disoriented."

Efforts to increase one's ability to read and interpret maps have proved successful, but this learned ability does not provide an innate sense of direction or orientation. Such an effort only provides one with the ability to better distinguish between what is and is not provided on a standard map. Navigation problems that lead to pilot disorientation are an area addressed by McGrath and Borden (6) in the following:

(1) "Disorientation is an insidious process, that can persist for long periods of time without the pilot realizing he is lost. Wanting to believe that the aircraft is still on the planned track leads the pilot to develop expectancies about what he will see outside the aircraft and false hypotheses are often made about the identify of features on the ground. These erroneous identifications are maintained despite much contradictory information."

(2) "The experience of geographical disorientation can be so compelling that the pilot can become absolutely convinced that his instruments or maps are wrong and formerly familiar surroundings can suddenly appear unfamiliar."

(3) "Conflicting cues under geographical disorientation can produce marked emotional stress, confusion, and preoccupation."

From the previous discussion, it is obvious that navigating with a map can lead to geographic disorientation. To assist in overcoming this problem and as the first step in providing the Army aviator a self-contained navigation system, the US Army has recently adopted the Lightweight Doppler Navigation System (LDNS), AN/ASN-128. In a detailed review of many typical Army aviation missions, the Project Manager for Navigation and Control Systems (NAVCON) concluded that a proper mix of existing navigation equipment could provide both the capability and cost effectiveness to complete most missions assigned (3). NAVCON concluded that a navigation system should weigh approximately 30 pounds, cost less than $20,000 (1975 dollars), have a Mean Time Between Failure (MTBF) of 1000 hours and provide position accuracy of 25-250 meters.

The purpose of any navigation system is to provide the aircrew with reliable information in a timely manner, and in a usable form. However, with the LDNS one must navigate by reference to a digital display interpolated to a standard paper map and then to a ground reference. Since the Doppler digits presented are normally UTM coordinates, one must relate or transpose this series of 13 alphanumerics to some map or terrain feature. This interpolation process is susceptible to error and increases workload. This increase in workload does not include the additional work of updating the navigation system to insure its accuracy. In combat these functions must be performed over relatively unfamiliar terrain at NOE altitudes both day and night. At night and during flight operations in reduced visibility, these functions must be performed with visual ranges sometimes less than one-quarter of a mile. Effective use of this system is also adversely affected by current maps. Instead of having an aerial overview of the terrain and its respective features, NOE flight is conducted in an altitude regime, that renders most of the maps cartographic features useless.

The use of a Projected Map Display (PMD) or an Automatic Map Reader (AMR) would be a logical step for increasing navigational accuracy and reducing the workload required during NOE navigation. Information presented on a visual display for ready use by the navigator greatly reduces the interpolation task and potential for error. Such a display also provides the navigator with the ability to look ahead in anticipation of checkpoints or for updating the navigation system. These features make either the PMD or AMR ideal candidates for integration into existing and proposed helicopters. A recent test conducted by the US Army Aircraft Development Test Activity (USAADTA) (9) clearly demonstrated the increased navigation performance of pilots using a PMD. This test compared the navigational capabilities of pilots during both daylight and night flights over several NOE courses. The test subjects performed navigation tasks using either a standard map, a standard map with the LDNS, or a Projected Map Display (PMD). Mean times to complete a course were used as a measure of effectiveness. The mean number of misorientations was also recorded and reported. Use of a PMD allowed the subject pilots to complete a day flight course in less than half the time required to complete the course using only a hand-held map (13 minutes versus 28 minutes). Similar times were recorded during night flights. A significant workload reduction by the pilot/navigator when using a PMD was also reported. There were no misorientations reported when using the PMD while 25 misorientations were recorded while using either the hand-held map singularly or the hand-held map with Doppler.

A visual presentation of relative position can serve as a strong, positive reinforcement in any navigation task. From a review of the causes of disorientation which could be ascribed to deficiencies in maps and navigation displays, Bard concluded that automated moving map displays would reduce disorientation significantly (2).

METHOD

The US Army Human Engineering Laboratory (USAHEL) recently flight tested the Marconi Avionics Automatic Map Reader (AMR) in an attempt to address some of the human engineering principles involved in navigation devices. The Marconi AMR was installed aboard a JUH-1H helicopter equipped with a Doppler Navigation System. The AMR received its input from a (LDNS) AN/ASN-128 that has been calibrated to provide not more than 3.5% cross track error and less than 2% along track error. The Marconi AMR display head and 8 feet of interface connector cable weigh 2.3 Kg. The interface unit was rack mounted and also weighs 2.3 Kg.

Six Army aviators performed navigation duties with the Marconi AMR during its flight assessment. Each subject was provided a ground briefing of the Marconi AMR concerning the function of the various switches and a general orientation as to the AMR's in-flight operation. The subjects were then given an in-flight orientation and familiarization period with the AMR.

Following the familiarization flight (30 minutes to 1 hour), the aircraft was set up on a pre-plotted navigation course with the AMR set on the start point. Each subject navigator was then asked to provide the instructor/safety pilot verbal guidance to maintain a displayed flight track along the 13 Km plotted map course. Upon completing this navigation task, each navigator was asked for his comments regarding the AMR and its operation. Comments were also solicited from the subjects by the safety pilot/experimenter regarding various switch functions or the navigator's ideas on what other functions he would desire in an automatic map reader.

No attempt was made to objectively measure the relative or absolute accuracy of the navigator during these portions of flight trials. A typical navigator comment sheet is included in the Appendix.

SYSTEM DESCRIPTION AND ASSESSMENT

This section is organized to provide two objectives: (a) a detailed description of the Marconi AMR and it's associated modes of operation; and, (b) subjective assessments by pilot personnel as to the AMR's utility as an operational navigational aid.

The Marconi Automatic Map Reader (Figure 1) is a thigh-mounted, portable, lightweight, micro-processor controlled device. It allows the display of helicopter position and stores waypoints both numerically and cartographically. The AMR display head is connected via a cable to an interface unit. The interface unit receives and decodes the position, waypoint, and status information. This is obtained from the auxillary digital output of the AN/ASN-128 Lightweight Doppler Navigation System. The interface unit also converts the aircraft supplied 28 Vdc power to 5 Vdc for operation of the AMR display head.

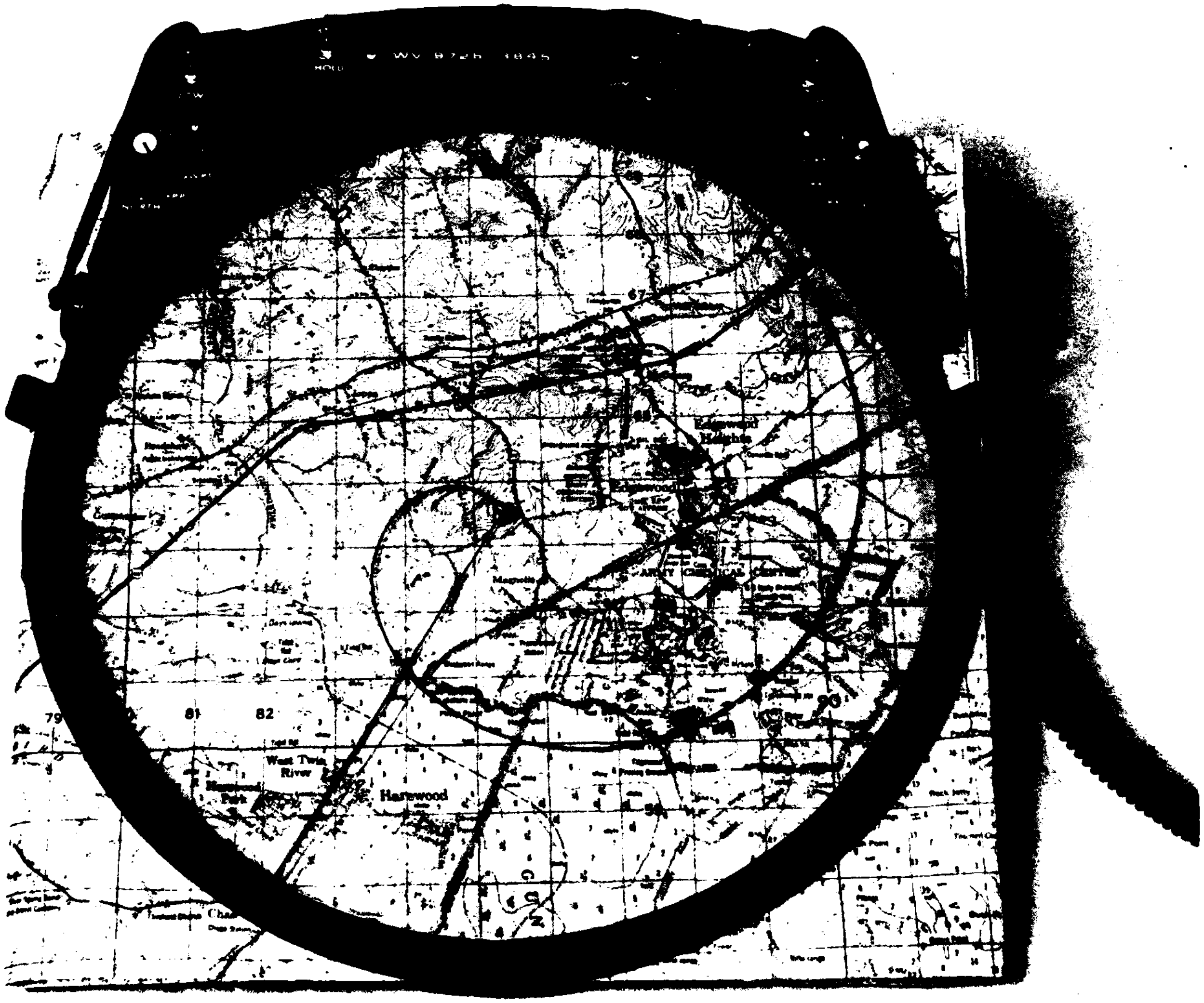

Figure 1. Marconi Automatic Map Reader (AMR).

The AMR display head, shown in Figure 2, is a two-piece latching clam-shell. The bottom piece contains the display electronics. The top half is composed of the transparent etched disks, the driving motors, and the control panel. One disk is etched with a spiral line, the other with a radial line. A carrying strap is connected to the top of the display head. The cable that connects the interface unit is also connected to the bottom piece of the display head (Figure 3). The display head contains an eight-bit micro-processor with (16K) bytes of program memory and (1K) bytes of random access memory. Modulation circuitry for illuminating the light emitting diodes (LED's), stepper motor drivers, display drivers, and multiplexing circuitry is also mounted in the display head. The two stepper motors drive a set of gears that rotate the two transparent disks. The intersection of the two etched lines then indicate a map position.

As the Doppler inputs change, the ruled lines on the two disks move to show the helicopter position on the map. The UTM coordinates are also displayed as an alphanumeric in the display window of the control panel. The selected mode of operation is also displayed; i.e., present position (PP), target (TGT), waypoint (WPT).

SETUP AND LOADING

The Doppler must first be set to the correct coordinates. The map is folded and inserted into the AMR head. The unit is turned on and set to the correct map scale (i.e., 1:50,000, 1:100,000, or 1:250,000). The AMR head must be aligned with map grid north by slewing a set of index markings on the disk head. This orientation is read into memory. Present position (PP) is set by slewing the intersection of the etched and radial lines over the present position and a READ command entered. The UTM coordinates are displayed by a set of light-emitting diodes (LED's) in a display window at the top center of the AMR. None of the pilots experienced any difficulty in inserting, aligning, or in setting their present position. Pilots would normally insert the map with their present position located at the bottom of the AMR so that their flight course was oriented toward the top of the AMR. The initial setup of the AMR took approximately 2 minutes to complete. At a viewing distance of approximately 20 inches, a map reading error of $\pm$20 meters existed (1:50,000 map) due to parallax and angular uncertainty. This angular uncertainty is caused by the intersection of the etched lines over the map face. The navigator normally held the AMR or placed it on his lap.

WAYPOINTS AND TARGETS

The AMR provides the capability to store 16 waypoints (WPT) or targets (TGT). This is accomplished by setting the mode select switch to either WPT or TGT and slewing the etched lines to intersect the desired WPT or TGT and pushing READ. The AMR would display the eight-digit grid coordinate of the

Figure 2. Marconi AMR opened.

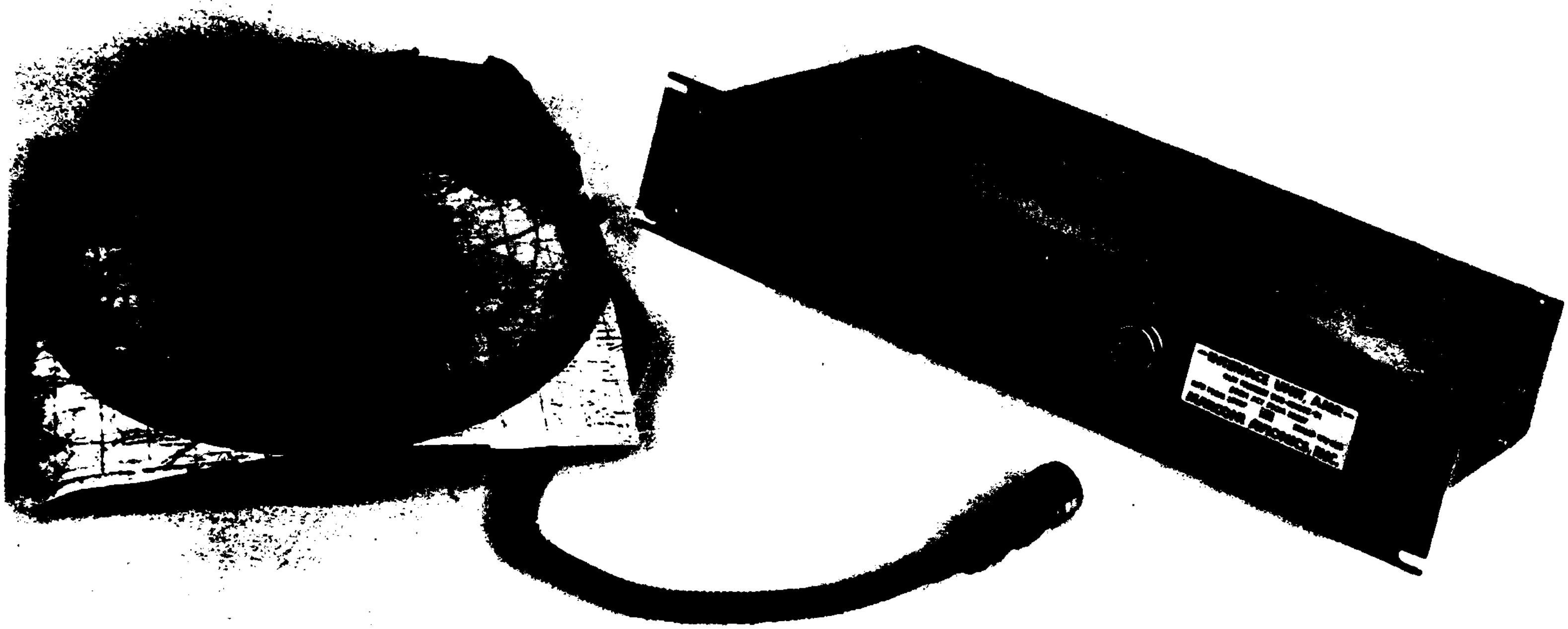

Figure 3. The Marconi AMR and interface unit.

selected point while continuing to track present position in memory. The ability to store waypoints would prove very helpful in providing update information to the Doppler Navigation System. This feature was not available during this study since the AMR could not address the Doppler Navigation System. The AN/ASN-128 Doppler does not allow an external access to its computation system, but only provides a data output. This is considered a disadvantage as it degrades the navigation systems utility. Marconi Avionics personnel have stated that an update capability is feasible given an input capability to the Singer AN/ASN-128 Doppler. The prototype AMR provided to USAHEL for testing did not have a back-up battery power capability, and all memory and display functions of the AMR were erased any time the aircraft electrical power was shut off. Marconi engineering personnel stated that they were planning to provide back-up power (i.e., battery). Another problem with the non-interactive AMR-Doppler interface is that it requires a manual Doppler keyboard entry to effect a visually displayed position update or to obtain the distance, bearing, time, or steering commands to a selected destination or waypoint. This increases workload while degrading system performance.

MAP ROLLOVER

A large scale map (1:50,000 scale or larger) is normally used for NOE navigation. When folded and inserted in the AMR, an area of 140 square kilometers is displayed. This equates to roughly 12 kilometers of straight line distance before reaching the edge or no track area of the AMR. Upon reaching a rollover point on the map, a Hold command must be entered in the AMR. The map is then removed and refolded so that the cartographic feature where the Hold command was entered is included on the map area now being used. This is both cumbersome and time consuming unless overlapping map areas are pre-cut or multiple pre-folded map sheets are used. After reinserting the map, it is still necessary to orient the AMR to grid north and to set the intersecting lines over the previous map area Hold position. The AMR will slew to the present position based on information stored in the memory of the AMR. There is no method presently available to show when the AMR has reached its tracking limit other than to observe no movement of the intersecting lines for a period of time. A flashing NO TRACK statement in the display area would provide an immediate indication of an out-of-track position. This would enhance the AMR's ability to maintain a correct map position.

LIGHTING

The LED coordinates and mode display window were the only lighting supplied with the model tested. The brightness of the display was controlled by means of a rheostat located adjacent to the display window. The display window was covered with a 3M lovered film that provides a viewing angle of 30 degrees. There was some difficulty in reading the display when the AMR was mounted on the thigh. This was due to the viewing angle subtended being near the limit of the film viewing angle. The LED lighting was not checked with night-vision goggles to assess its compatibility. Marconi has been working with several techniques to provide illumination of the map display. This feature was not provided on the system tested.

OPERATION AND MAINTAINABILITY

The portability of the Marconi AMR makes it an ideal candidate for installation into existing helicopters equipped with a Doppler Navigation System. No system failures were noted during testing and the AMR has proven quite durable. There has been a tendency for dust to collect between the two etched disks. Some very minor scratches were made on the plexiglass cover which might cause reflection problems on a lighted model. The mode and function switches should be modified in both position and size. The rotary switches seemed fragile and imprecise in their operations. The toggle switches used to slew the etched disks should be placed in close proximity to each other so that they could be operated simultaneously with one hand. The other toggle switches should be shape coded and positioned based on functional requirements. The power cord connector should be allowed to swivel through a limited arc. This would prevent binding of the AMR when orienting it to a track up mode. A system assurance check (BITE) needs to be added to assure that all components are functioning properly.

TRADEOFFS TO BE CONSIDERED BETWEEN AN AUTOMATIC MAP READER AND A PROJECTED MAP DISPLAY

There are advantages and disadvantages to both navigation systems when viewed separately or in comparison. Table 1 presents an AMR and PMD comparison of features available with the two navigation systems. This is not meant to be an all-inclusive performance evaluation, but lists some of the features desirable in navigation systems. The two major differences between the PMD and AMR are the cost factor and the installation in existing aircraft features offered by the AMR.

TABLE 1

AMR and PMD Comparison

	AMR	PMD
A/C Present Position	Yes: Also eight-digit grip coordinates.	Yes: Also displaced Present Position; i.e., centered or bottom.
Alternate Map Orientation (North and Track Up)	No: Orientation based on how map is inserted. Can be manually oriented in flight.	Yes: Gives either North Up or Track Up orientation.
Facility to Update	Yes: Does not update AN/ASN 128 Doppler due to Doppler System.[a]	Yes: Does not update AN/ASN 128 Doppler due to Doppler System.[a]
Target & Way-point Storage	Yes: Also provides associating grid coordinates.	Yes.
Ability to Annotate	Yes: Either directly on map or on face of display head.	No: Not without major modification to film cassette.
Selectable Map Scale	Yes: Any of three map scales.	Yes.
Ease of Installation in Existing Helicopters	Very Easy: Only interface unit is installed in standard radio console. Display head can be removed and taken to briefing room.	Moderate to Impossible: Requires minimum panel depth and dedicated panel space.
Cartographic Support	Minimal: Uses standard paper maps. No special support.	Extensive: Difficult to modify existing map cassettes. Requires major cartographic support.
Aircraft Track	No: Is not displayed.	No.
Range and Bearing	No: Only via the Doppler display with AN/ASN-128.	Yes: Bearing pointer and range to selected destination.
Cost	Approximately $8000, 1980.	$55,000-$60,000, 1980, plus installation and modification cost to current inventory A/C.

[a]The Doppler cannot be updated directly from the AMR or PMD due to current Doppler system.

SUMMARY

The majority of data reviewed in this flight assessment indicates that navigation at NOE altitudes has a high potential for geographic disorientation. NOE flight in a combat environment, without upgraded navigation equipment, will lead to greater attrition because of the inability to reach the desired destination on time and within a prescribed set of flight conditions; i.e., below detection altitudes.

The Marconi AMR offers a simple and inexpensive method of providing navigation information during helicopter flight in an NOE environment. The accuracy of the AMR is totally dependent on the Doppler navigation inputs. Its portability, annotation capability, ease of installation in existing fleet aircraft, and cost make it a very attractive interim navigation component.

The findings of this flight assessment provide an encouraging insight into the potential for map displays to assist US Army aviators in combat missions. It is recommended that a thorough examination on the military potential of map displays be performed. These tests would provide the operational community with data with which to determine cost/benefit tradeoffs to be considered related to improved combat efficiency.

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APPENDIX

FLIGHT ASSESSMENT OF THE MARCONI AVIONICS MAP DISPLAY

Flight Assessment of the Marconi Avionics Map Display

a. The letters and numbers are small in size, dimly lit and were sometimes very difficult to read.

b. The cord attached to the display case was an interference when turning the display for map orientation purposes.

c. No means is provided to determine the aircraft's direction of flight on the display, thus making it very difficult to navigate from point to point using only the map display.

d. It is suspected that the several toggle switches on the device would soon be broken and bent from normal use in the field. A sturdy means of performing their functions is required.

e. Some parallax in viewing the map and the position lines was noted.

f. A positive means of determining when the display is off the map is required. Several times during flight near the map edge no determination could be made as to whether the position shown on the display was an actual location or if the instrument had ceased to function, because the actual aircraft position was off the map and the display was recording the last known location.

g. A built-in test device could be included.

h. The ability to transfer coordinates from the map display readings directly to the Doppler would greatly enhance the system's capability.

i. The capability to read out latitude/longitude coordinates in addition to UTM coordinates would enhance the system's capability.